

Znanost na cesti

# Okusi osnovnih delcev in velike uganke zgradbe vesolja

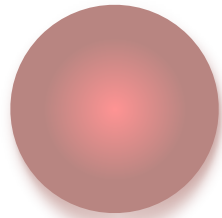
Jernej Fesl Kamenik, IJS in FMF

Nina Slaček, Radio Slovenija

2. marec 2023

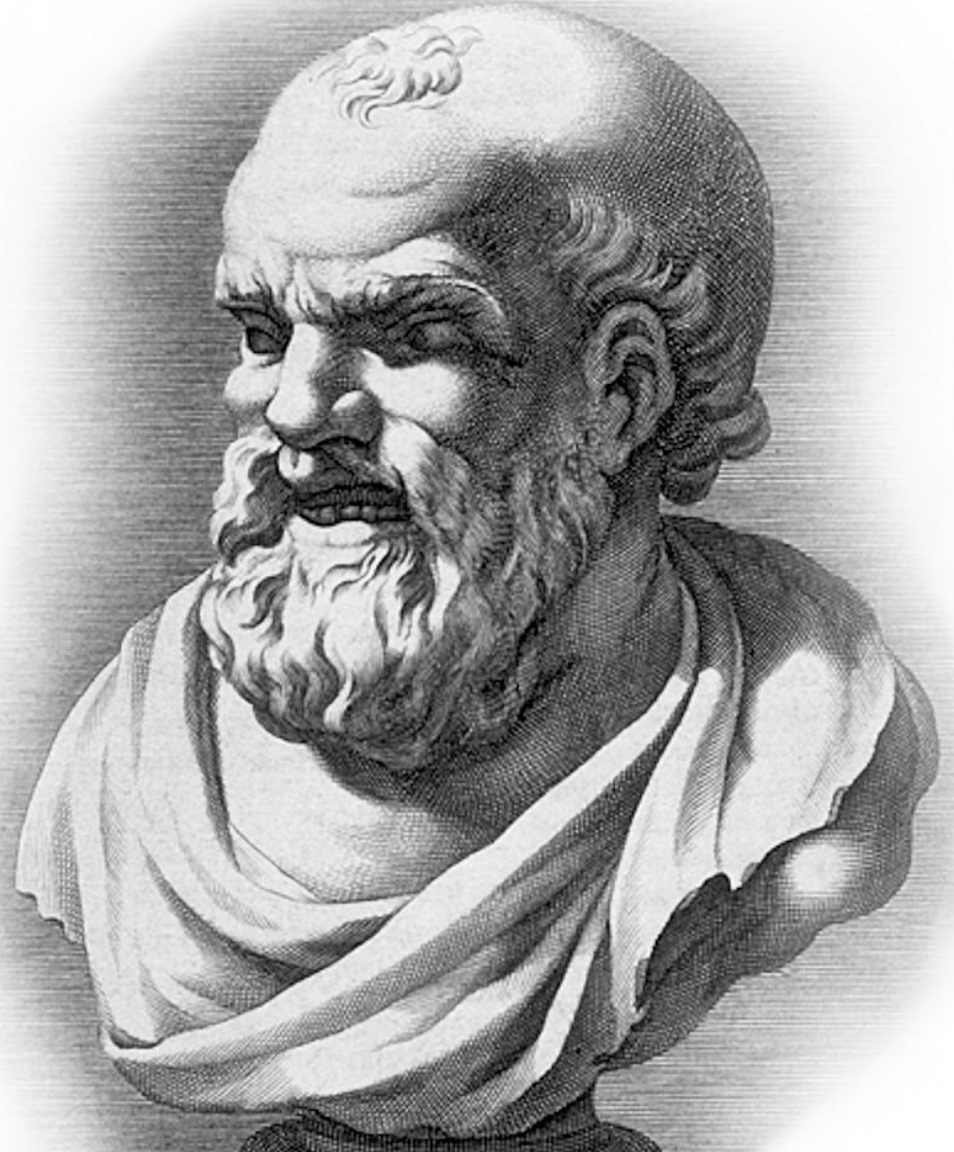


# Osnovni gradniki snovi



Atomi

(Demokrit idr., 4. stoletje p.n.š.)





m

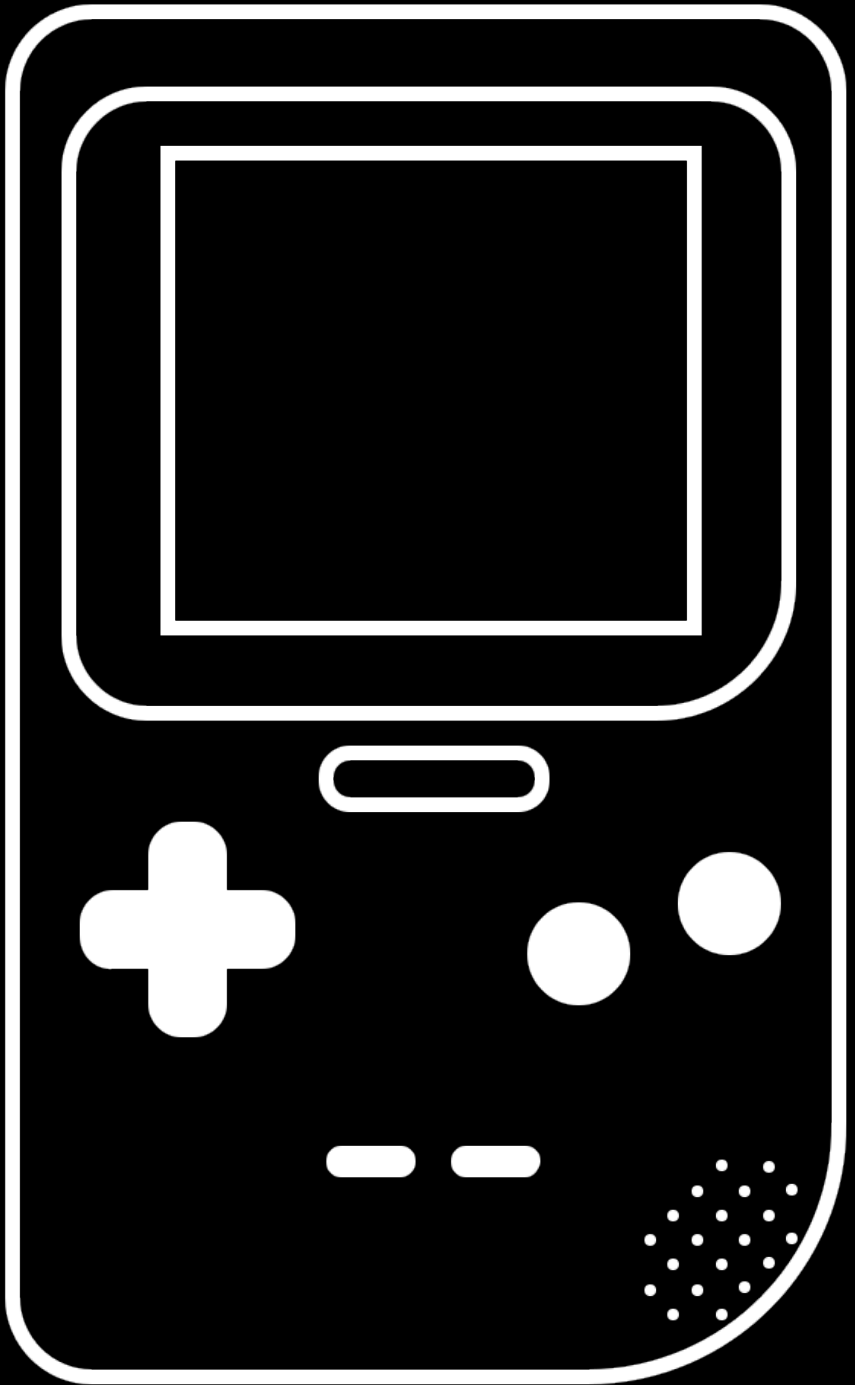
mm

$\mu\text{m}$

nm

pm

fm





m

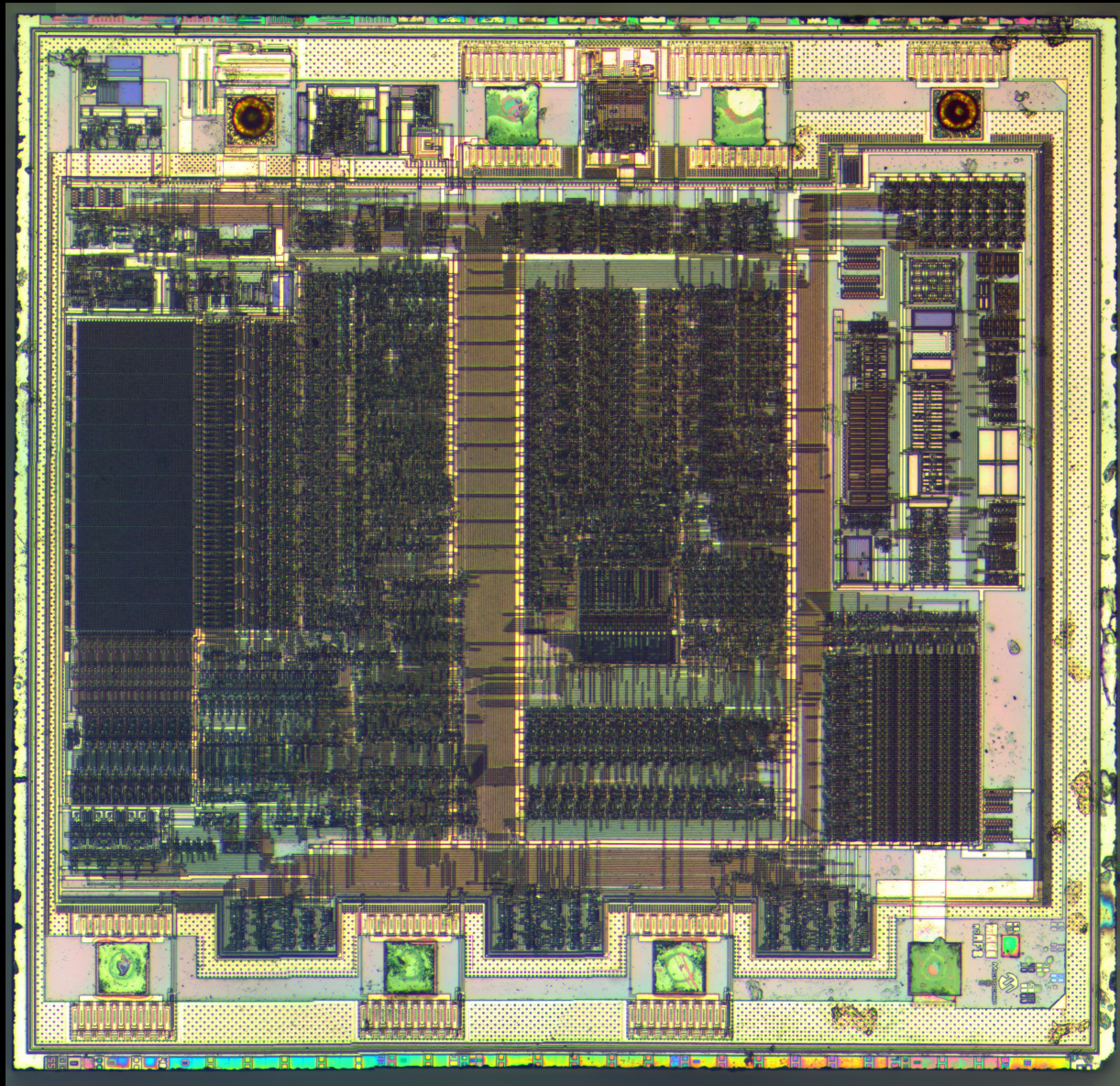
mm

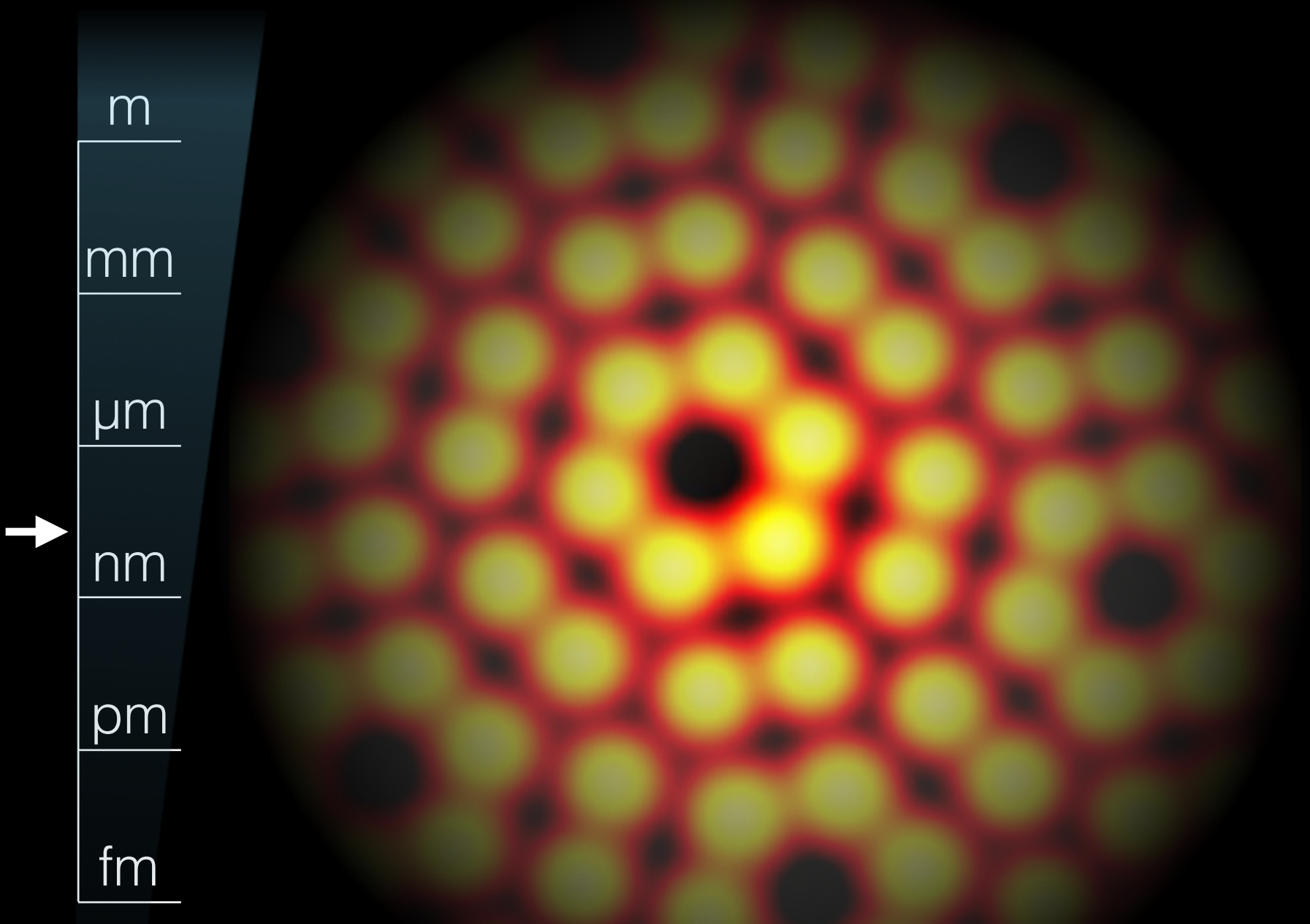
$\mu\text{m}$

nm

pm

fm





m

mm

$\mu\text{m}$

nm

pm

fm

Atomska struktura snovi  
(Dalton, Avogadro idr., 19. stoletje)

m

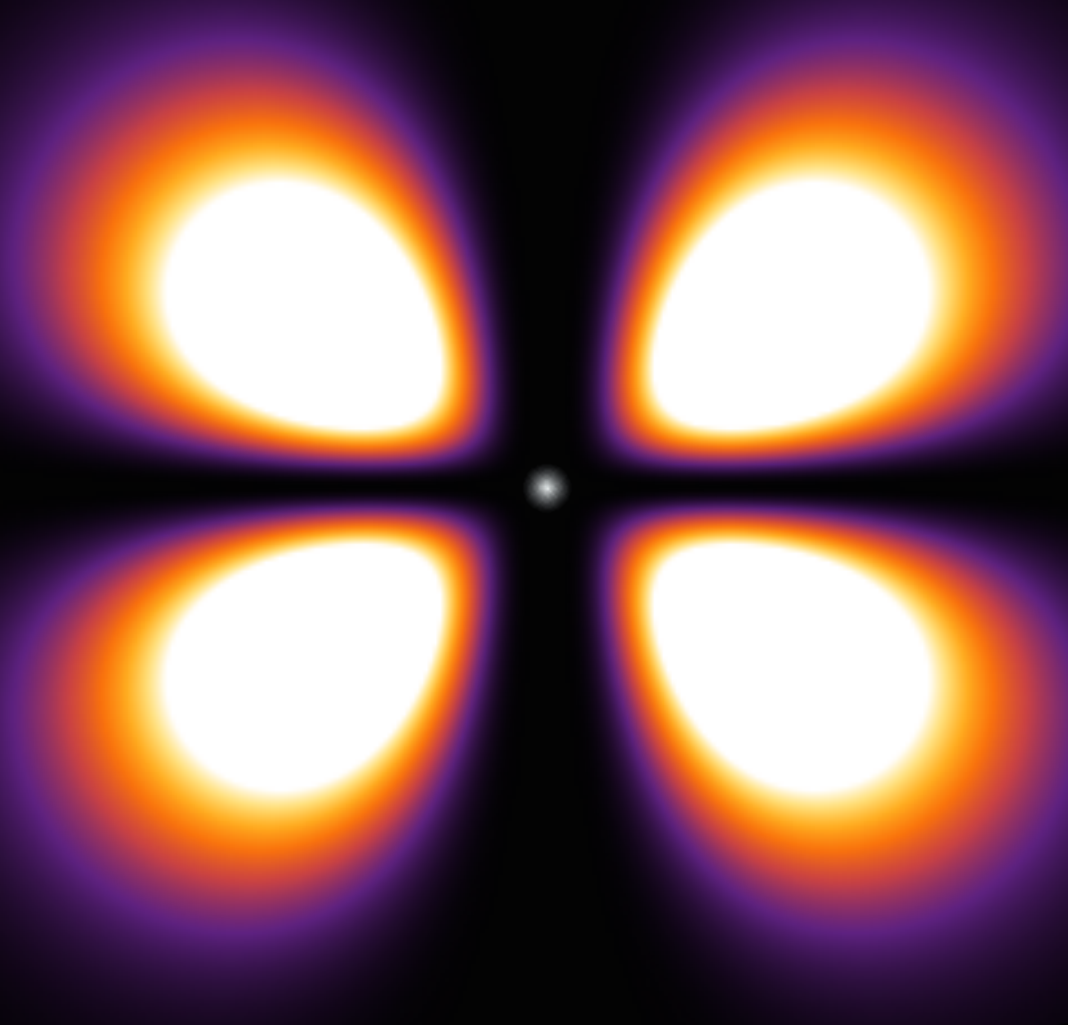
mm

$\mu\text{m}$

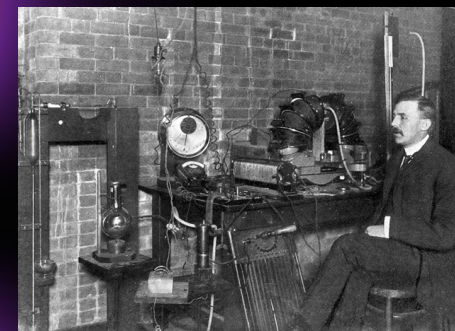
nm

pm

fm



e



Odkritje elektrona (Thomson, 1897)



Odkritje atomskega jedra (Rutherford, 1909)

m

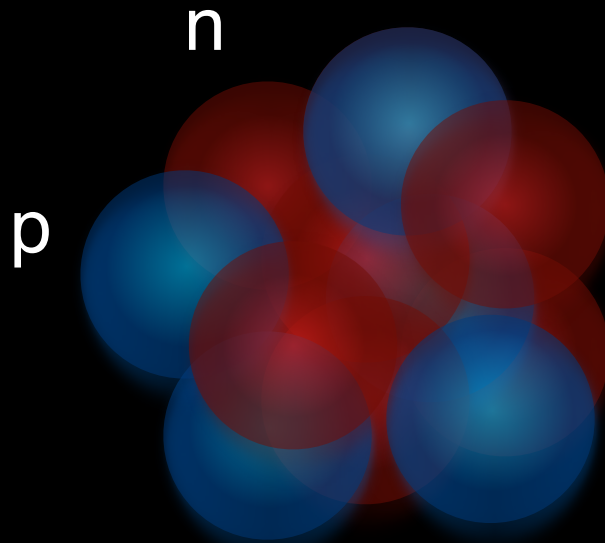
mm

$\mu\text{m}$

nm

$\mu\text{m}$

fm



Odkritje nukleonov  
(proton - Rutherford, 1917;  
nevtron - Chadwick, 1932)



m

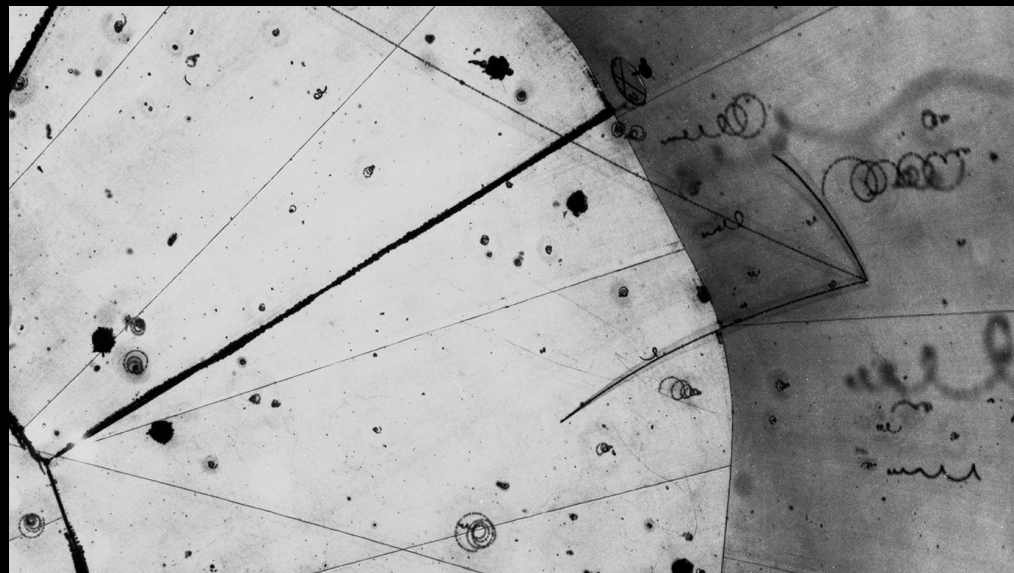
mm

$\mu\text{m}$

nm

pm

fm



odkritje (elektronskega) nevtrina  
(Reines, Cowan, 1956)

Volume 8, number 3

PHYSICS LETTERS

1 February 1964

A SCHEMATIC MODEL OF BARYONS AND MESONS \*

M. GELL-MANN

*California Institute of Technology, Pasadena, California*

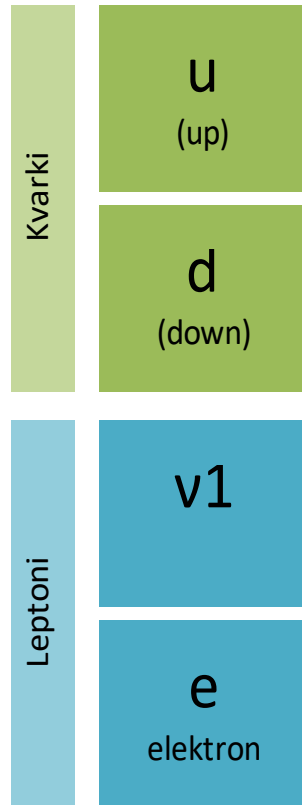
Received 4 January 1964



Kvarkovska struktura nukleonov  
(Gell-Mann, Zweig, 1964)



# Standardi model osnovnih delcev?



# Standardi model osnovnih delcev in sil?

Fermioni (snov, spin 1/2)

Kvarki	u (up)
	d (down)
Leptoni	$\nu_l$
	e elektron

Bozoni (sile)

$\gamma$ foton	(spin 1)
Z	
W	(spin 0)
g gluon	
H Higgsov bozon	

Feynman, Schwinger & Tomonaga, 1948



Glashow, 1961;  
Weinberg, Salam, 1967



Wilczek, Gross & Politzer, 1973



Higgs, Brout, Englert, Guralnik, Hagen, Kibble, 1964

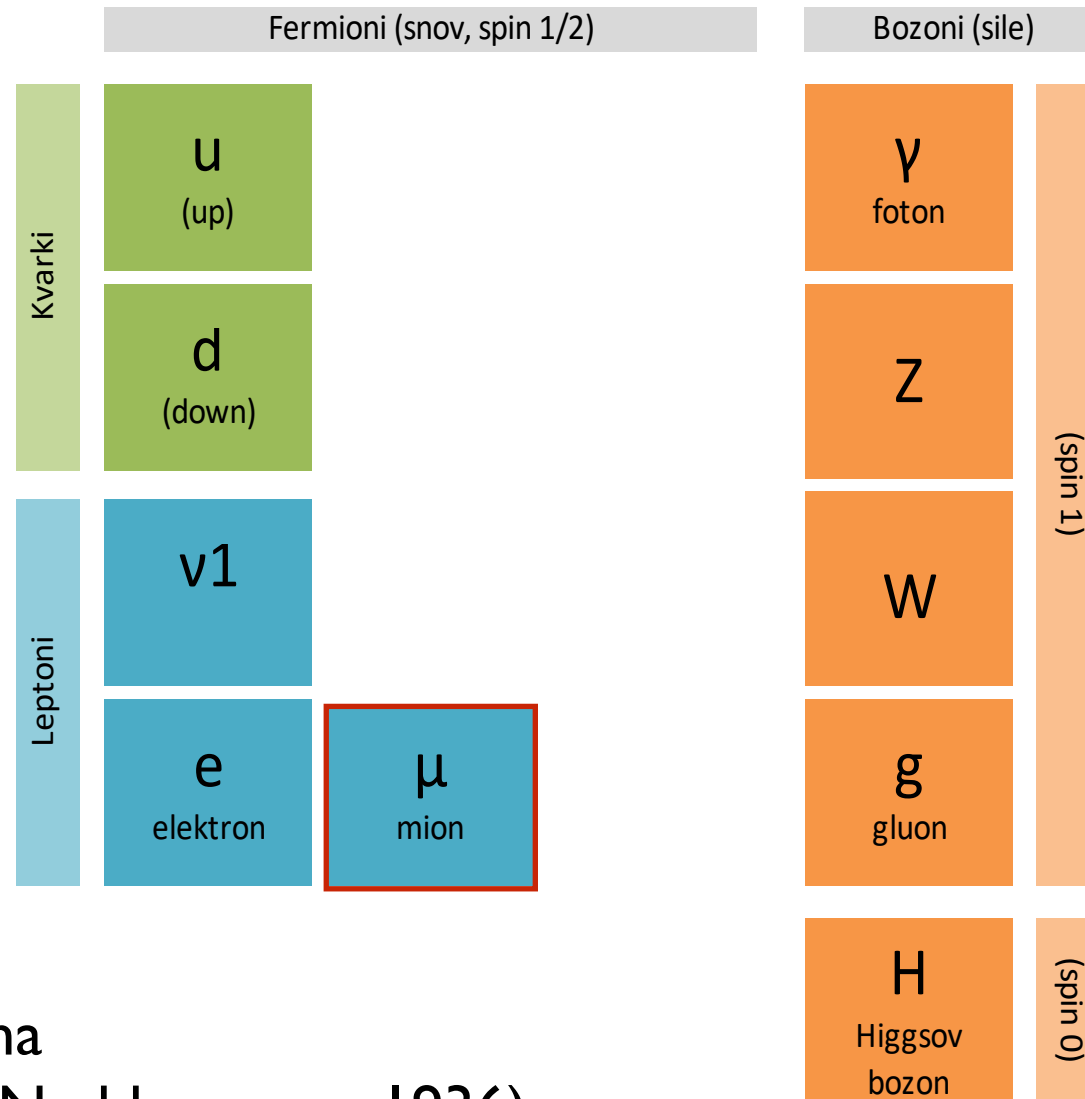


# Who ordered that?

(Kdo je to naročil?)

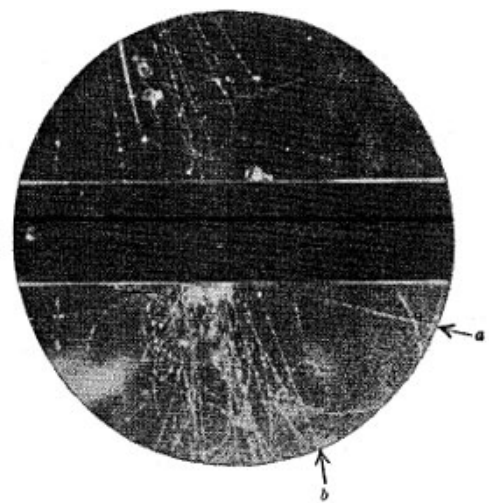
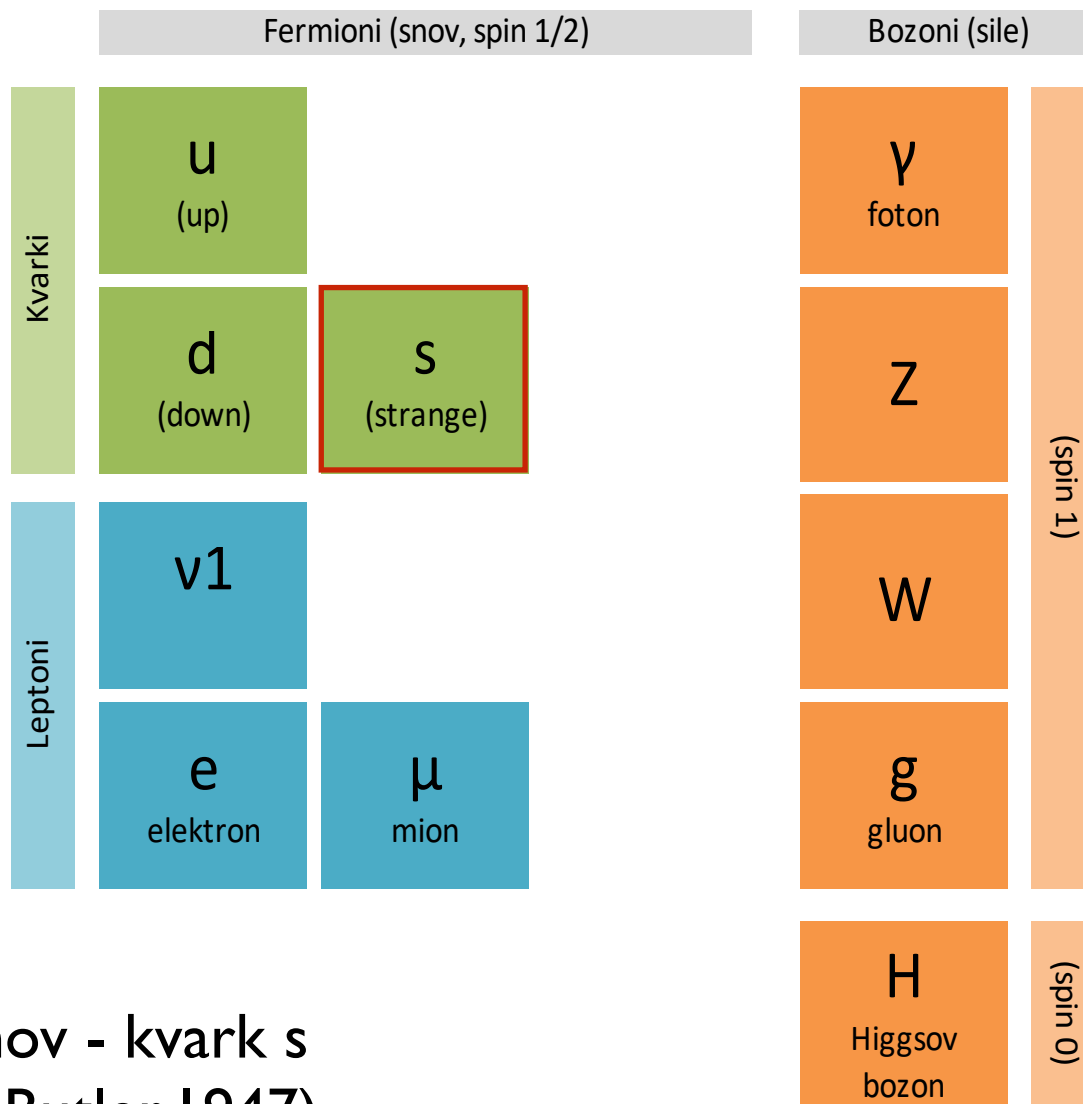
I. I. Rabi

# Okusi osnovnih delcev



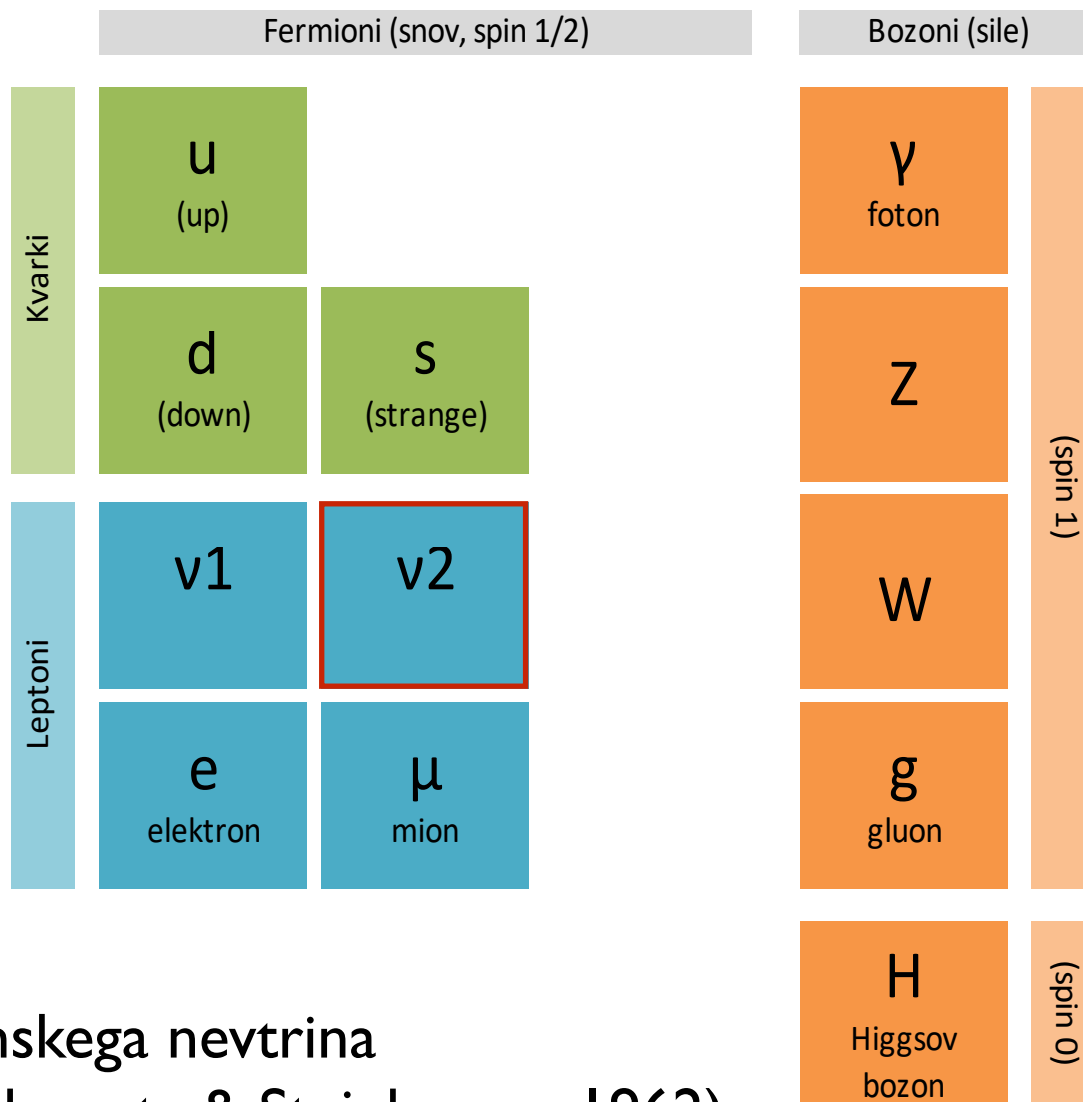
Odkritje miona  
(Anderson & Neddermeyer, 1936)

# Okusi osnovnih delcev



Odkritje kaonov - kvark s  
(Rochester & Butler, 1947)

# Okusi osnovnih delcev



Odkritje mionskega nevtrina  
(Lederman, Schwartz & Steinberger, 1962)



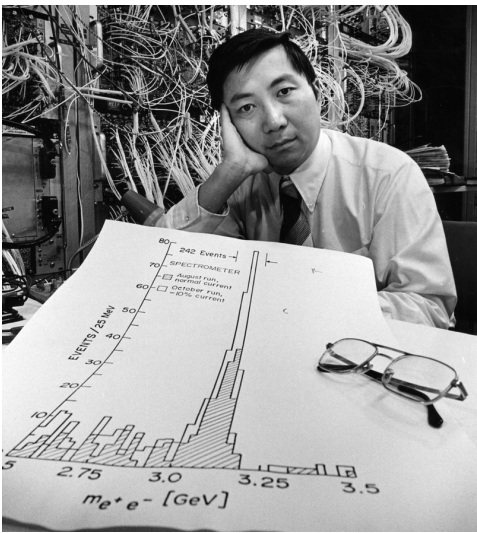
# Okusi osnovnih delcev

Fermioni (snov, spin 1/2)

Bozoni (sile)

Kvarki	u (up)	<b>c</b> (charm)
	d (down)	s (strange)
Leptoni	$\nu_1$	$\nu_2$
	e elektron	$\mu$ mion

$\gamma$ foton	(spin 1)
Z	
W	(spin 0)
g gluon	
H Higgsov bozon	

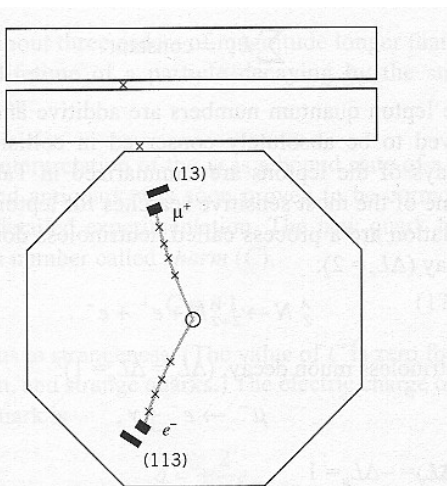


Odkritje čarmonija - kvark c  
(Richter & Ting, 1974)



# Okusi osnovnih delcev

	Fermioni (snov, spin 1/2)			Bozoni (sile)	
Kvarki	u (up)	c (charm)		γ foton	(spin 1)
	d (down)	s (strange)		Z	
Leptoni	ν <sub>1</sub>	ν <sub>2</sub>		W	
	e elektron	μ mion	τ lepton tau	g gluon	
				H Higgsov bozon	(spin 0)



Odkritje leptona tau  
(Perl, 1974)



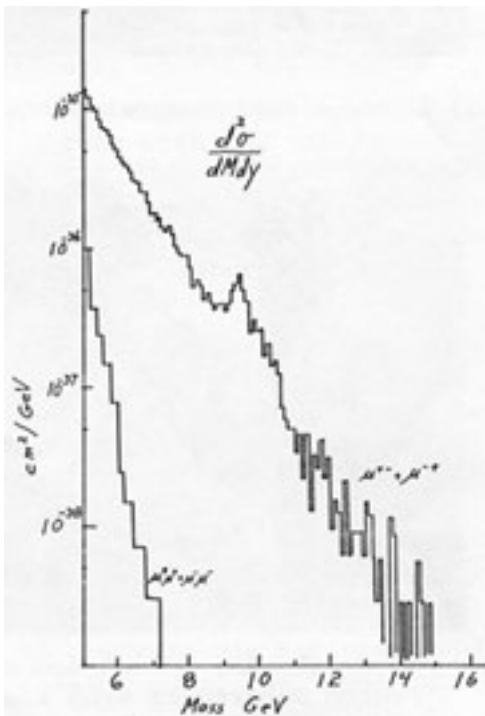


# Okusi osnovnih delcev

Fermioni (snov, spin 1/2)

Bozoni (sile)

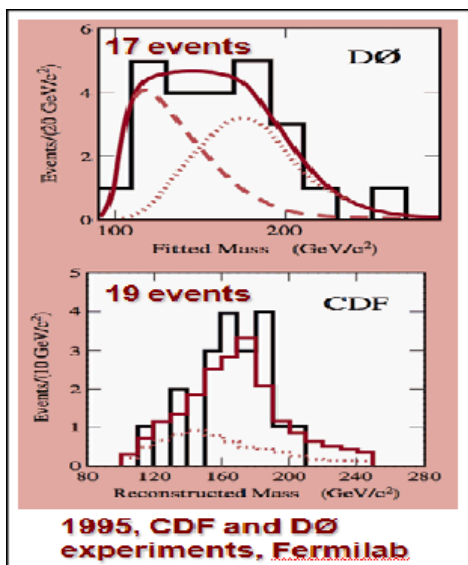
Kvarki	u (up)	c (charm)		γ foton	(spin 1)
	d (down)	s (strange)	b (bottom)	Z	
Leptoni	ν1	ν2		W	
	e elektron	μ mion	τ lepton tau	g gluon	
				H Higgsov bozon	(spin 0)



Odkritje botomonija - kvark b  
(Lederman, 1977)

# Okusi osnovnih delcev

	Fermioni (snov, spin 1/2)			Bozoni (sile)	
Kvarki	u (up)	c (charm)	t (top)	$\gamma$ foton	(spin 1)
	d (down)	s (strange)	b (bottom)	Z	
Leptoni	$\nu_1$	$\nu_2$		W	
	e elektron	$\mu$ mion	$\tau$ lepton tau	g gluon	
				H Higgsov bozon	

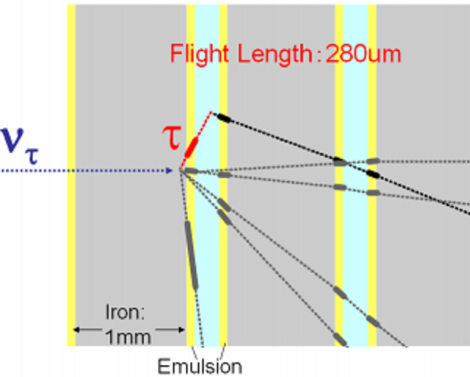


Odkritje kvarka t  
(Kolaboraciji CDF & D0, 1995)

# Okusi osnovnih delcev

Fermioni (snov, spin 1/2)      Bozoni (sile)

Kvarki	u (up)	c (charm)	t (top)	$\gamma$ foton	(spin 1)
	d (down)	s (strange)	b (bottom)	Z	
Leptoni	$\nu_1$	$\nu_2$	$\nu_3$	W	
	e elektron	$\mu$ mion	$\tau$ lepton tau	g gluon	
				H Higgsov bozon	

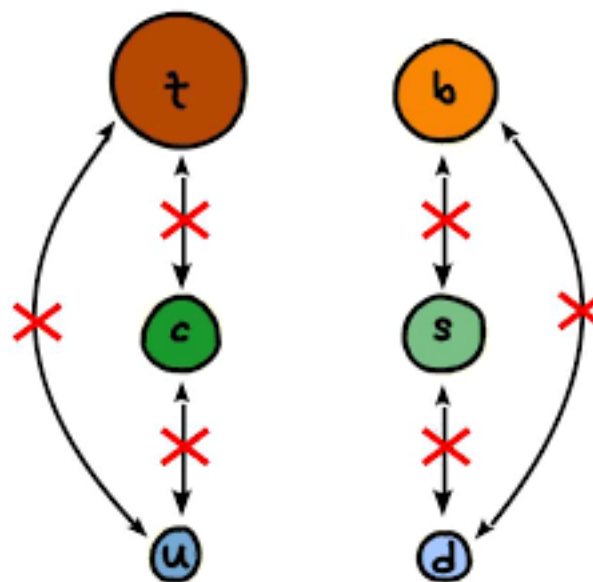
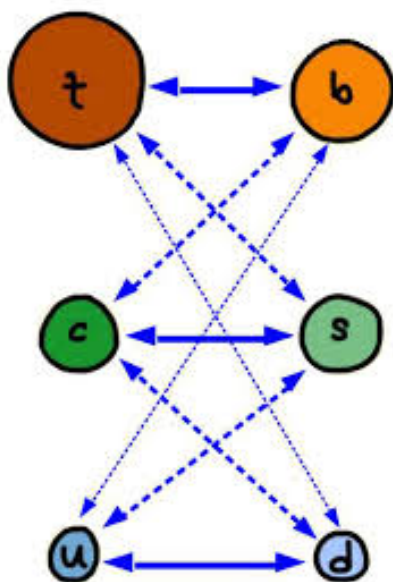


Odkritje tauonskega nevtrina  
(Kolaboracija DONUT, 2000)

# Standardni model osnovnih delcev and sil

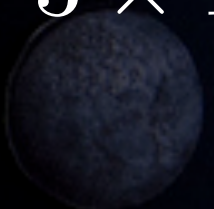
Fermioni (snov, spin 1/2)				Bozoni (sile)	
Kvarki	u (up)	c (charm)	t (top)	$\gamma$ foton	(spin 1)
	d (down)	s (strange)	b (bottom)	Z	
Leptoni	$\nu_1$	$\nu_2$	$\nu_3$	W	
	e elektron	$\mu$ mion	$\tau$ lepton tau	g gluon	
				H Higgsov bozon	(spin 0)

# Uganka okusov



# Uganka okusov

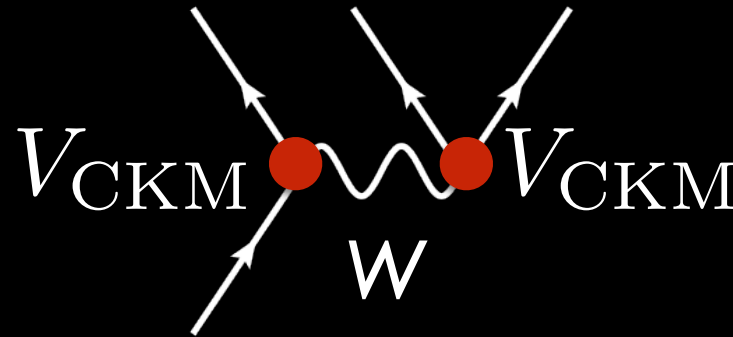

$$\frac{m_{\text{Pluto}}}{m_{\text{Jupiter}}} \sim 7 \times 10^{-6}$$


$$\frac{m_e}{m_t} \sim 3 \times 10^{-6}$$

# Uganka okusov



# Uganka okusov



$$V_{CKM} \sim \begin{pmatrix} & d & s & b \\ u & \text{large blue square} & \text{small pink square} & \text{dot} \\ c & \text{small pink square} & \text{large blue square} & \text{dot} \\ t & \text{dot} & \text{small pink square} & \text{large blue square} \end{pmatrix}$$

Cabibbo, 1963

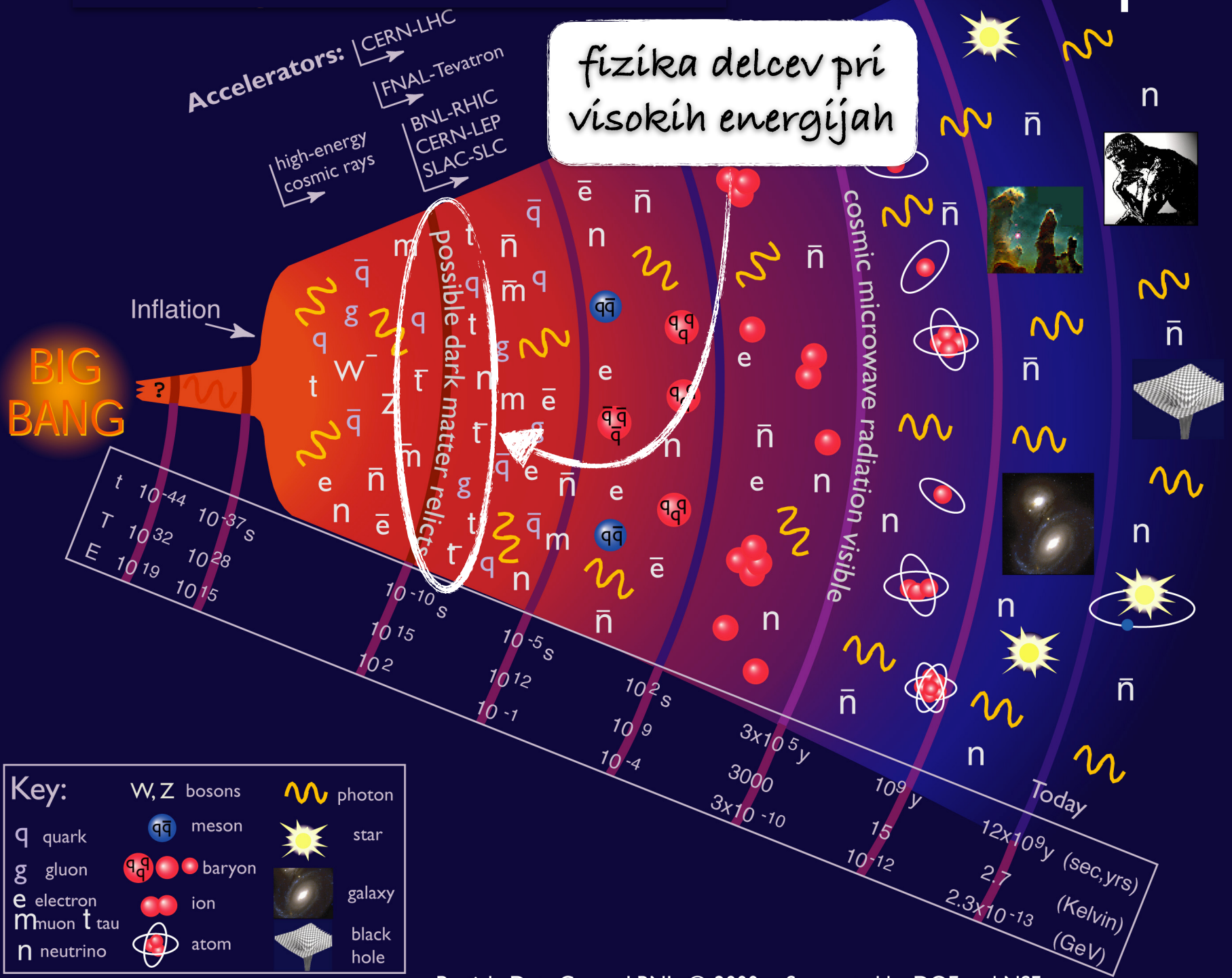
Kobayashi & Maskawa, 1973



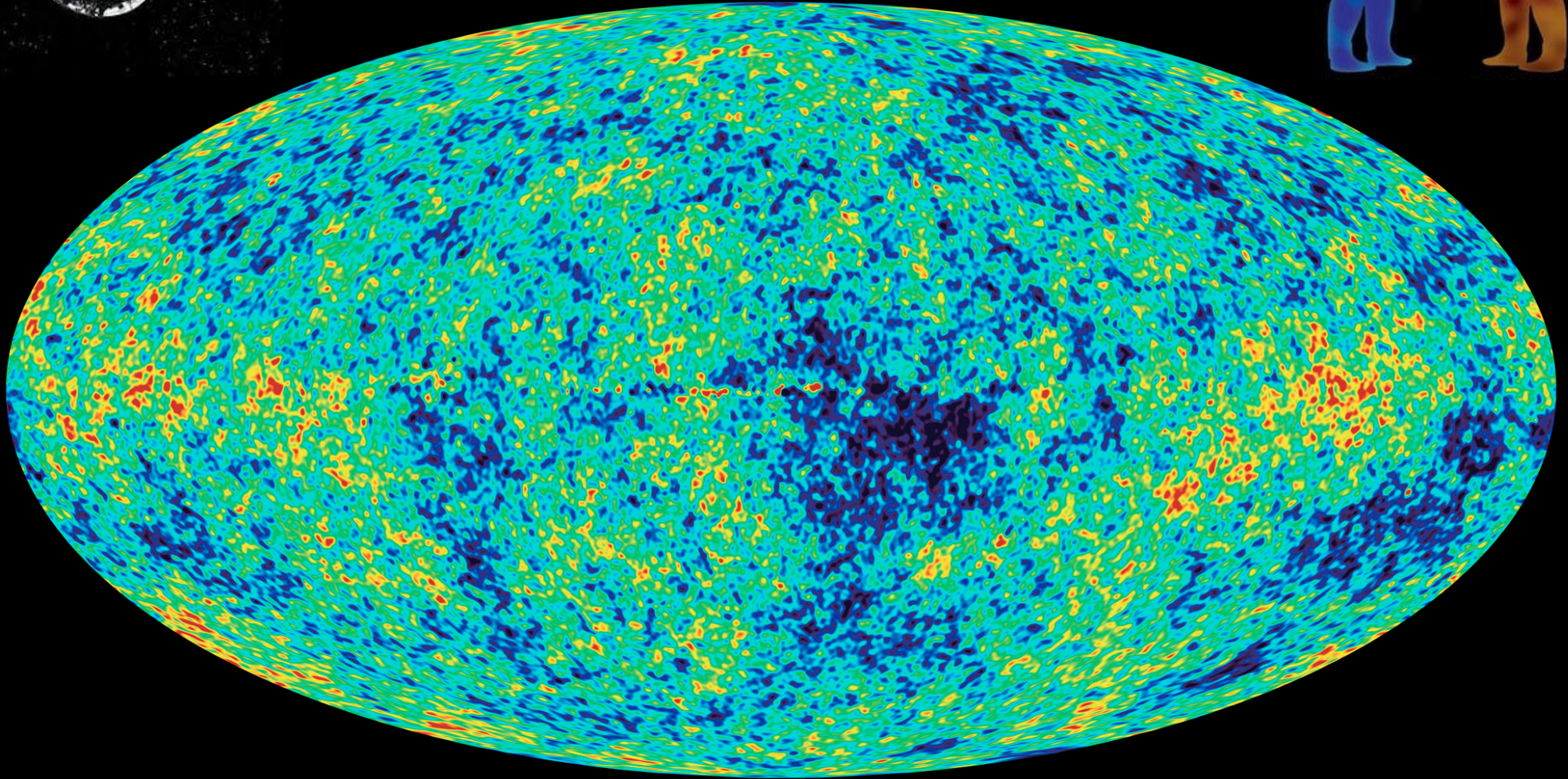


# Trkalniki delcev ~ kvantni teleskopi

fizika delcev pri visokih energijah

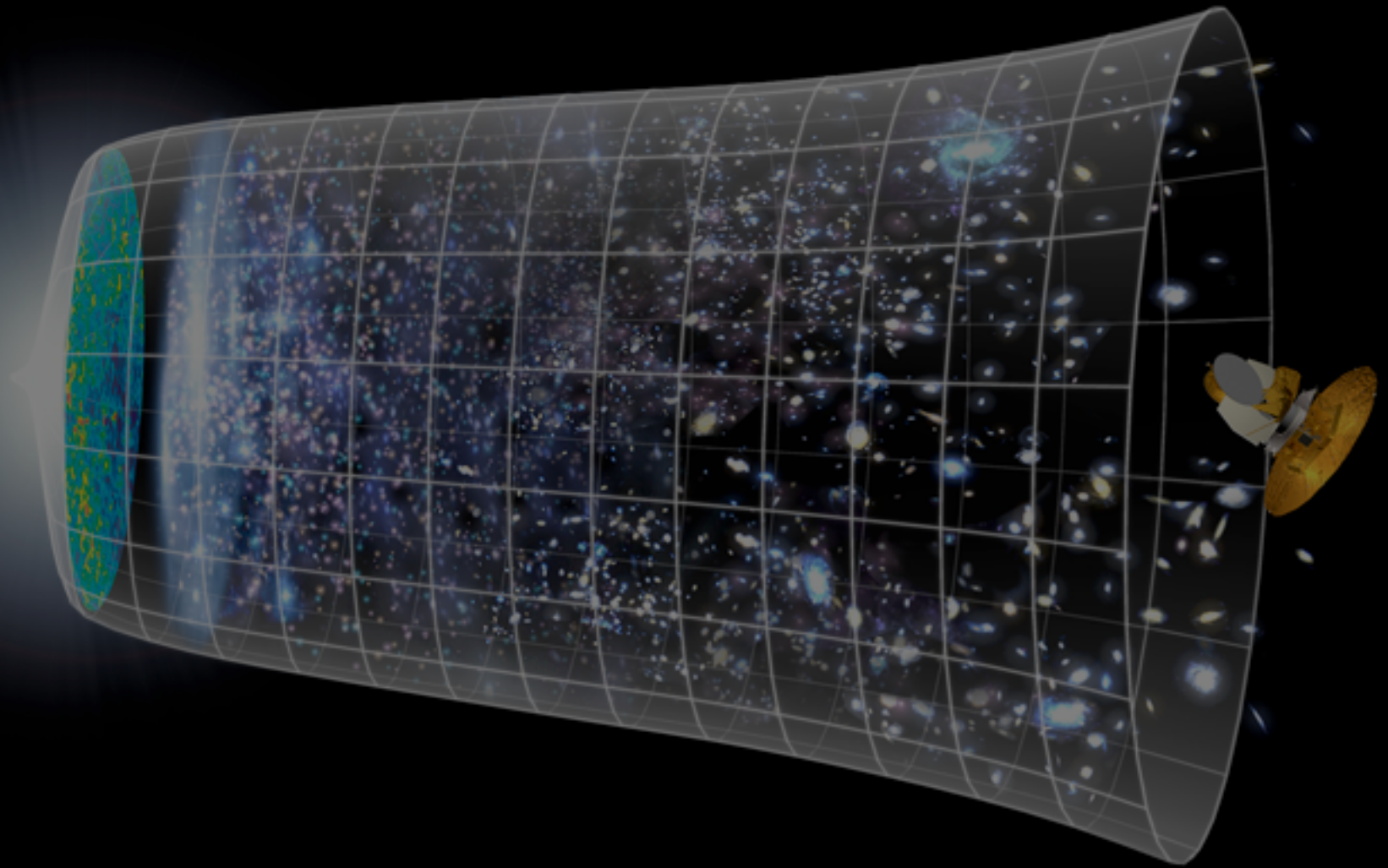


# Kozmično prasevanje

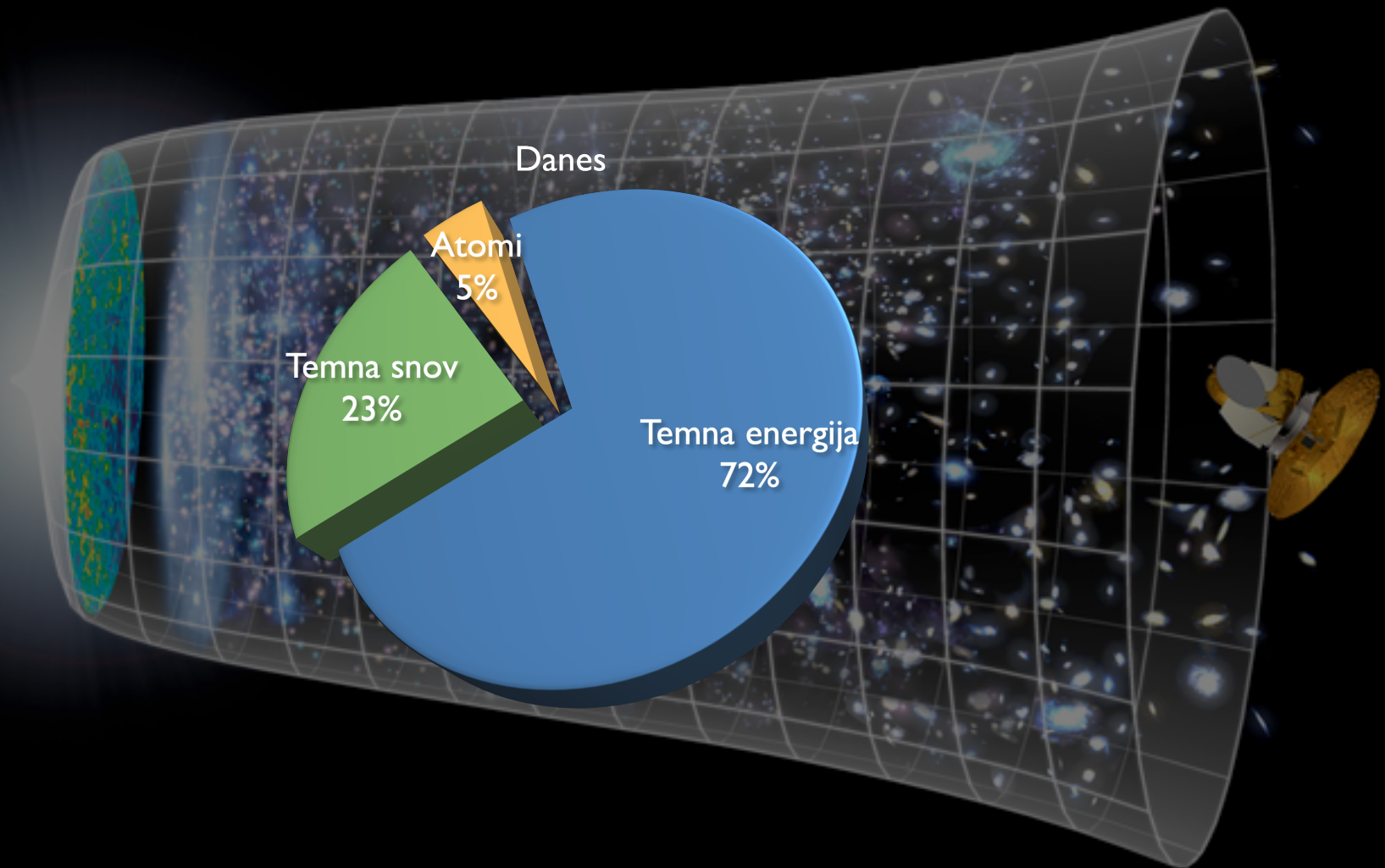


$\sim 0.0000000003$

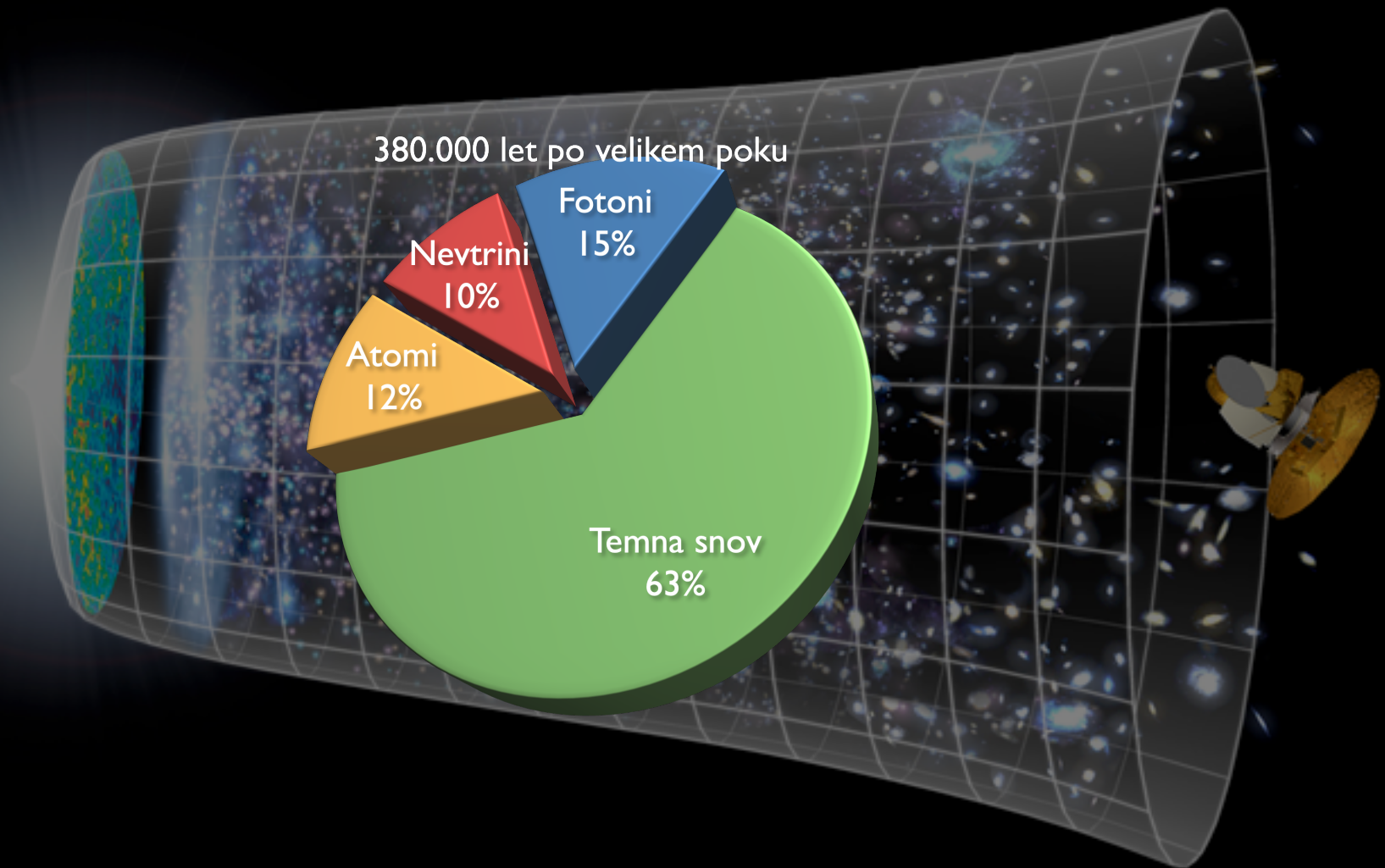
# Masa v vesolju



# Masa v vesolju



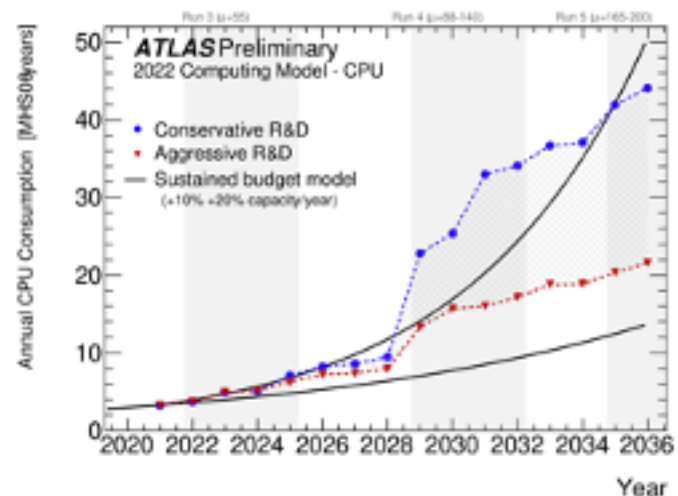
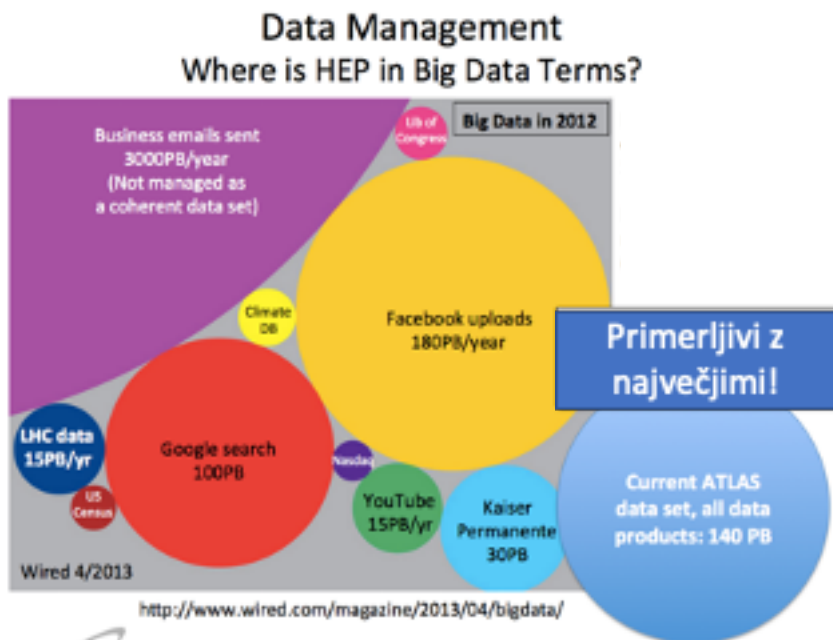
# Masa v vesolju



# Strojno učenje v fiziki delcev

Eksperimenti na LHC generirajo velikanske količine podatkov (milijarde trkov, 500 PB) in izziv se povečuje!

Uporaba najnaprednejših (super)računalnikov in računskih metod, kot je strojno učenje, je nujna!



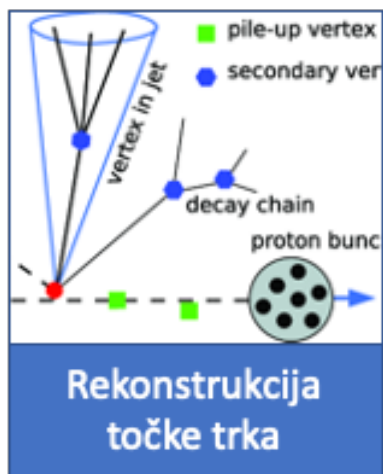
# Strojno učenje v fiziki delcev

V fiziki delcev (eksperiment in teorija) je uporaba strojnega učenja nekaj povsem rutinskega.

Danes ga srečamo na vsakem koraku...



Teoretski modeli



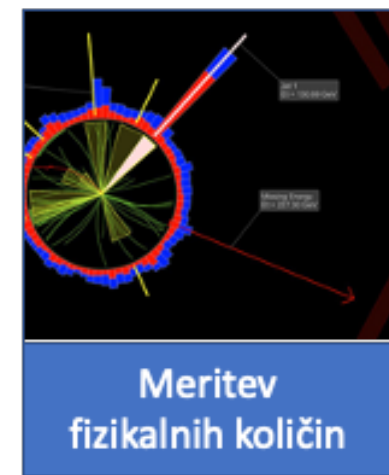
Rekonstrukcija točke trka



Dekodiranje dogajanja



Odstranjevanje šuma

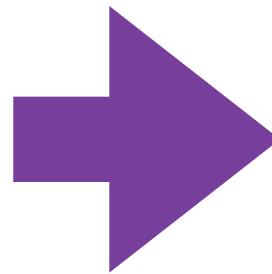
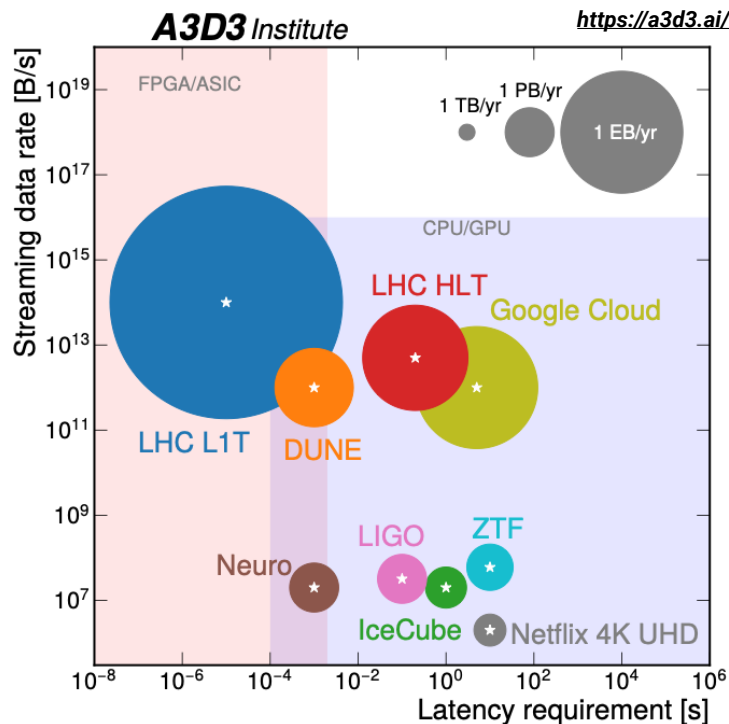


Meritev fizikalnih količin

# Strojno učenje v fiziki delcev

Prenos znanja iz fizike delcev v industrijo

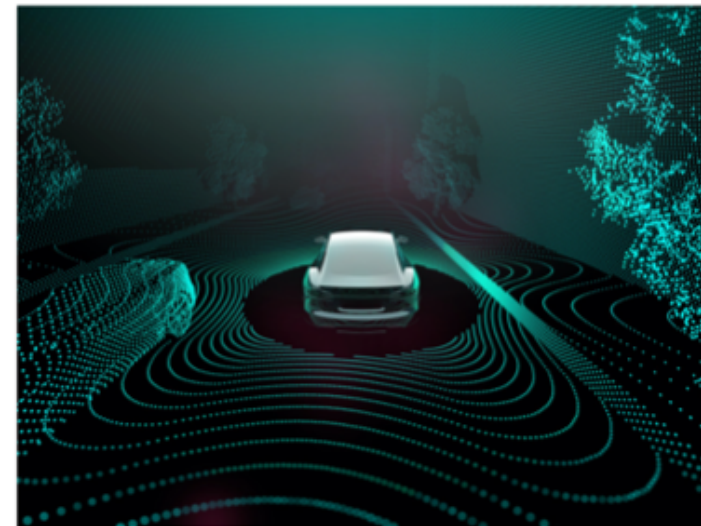
Primer iz področja strojnega učenja



## Colliding particles not cars: CERN's machine learning could help self-driving cars

CERN and software company Zenseact wrap up a joint research project that could allow autonomous-driving cars to make faster decisions, thus helping avoid accidents

25 JANUARY, 2023 | By Priyanka Dasgupta



CERN's expertise in machine learning could help the field of autonomous driving (Image: Zenseact)



# Strojno učenje v fiziki delcev

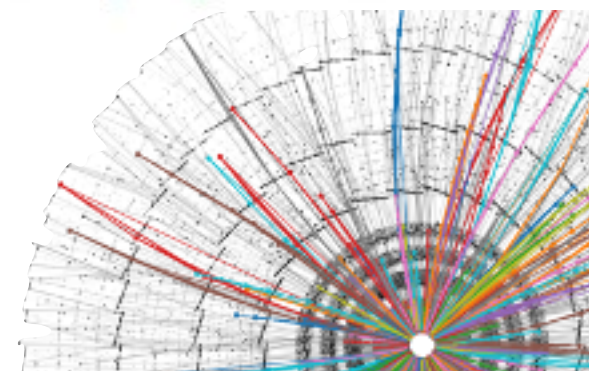
# SMASH

machine learning for science and humanities postdoctoral programme

Co-funded by  
the European Union



<https://smash.ung.si/>



Univerza v Ljubljani



Znanost na cesti

Okrogla miza:

# Prepoznavanje in obravnava demence

Moderatorka: Mojca Delač

4. april 2023

